Orientation to Computing-I

L T P :2 0 0

Unit-2 (Operating System)

- **Operating System:** Operating Systems and its components, Windows Operating Systems Versions and features, Installation process, Directory Hierarchy of Windows Operating System (single level and multiple level), Bootloader
- **Linux Operating System:** Linux OS and its features, Distribution versions, installation process, Directory Hierarchy of Linux System (single level and multiple level). Partitions: Understanding disk partitions and obtaining partition information using system tools, Comparison of windows and Linux OS, Virtual Machines

What is an Operating System?

- **What is an Operating system?**
  - **A program that acts as an intermediate/ interface between a user of a computer and the computer hardware.**
  - **Resource allocator (Managing the resources efficiently)**
  - **Control Program**

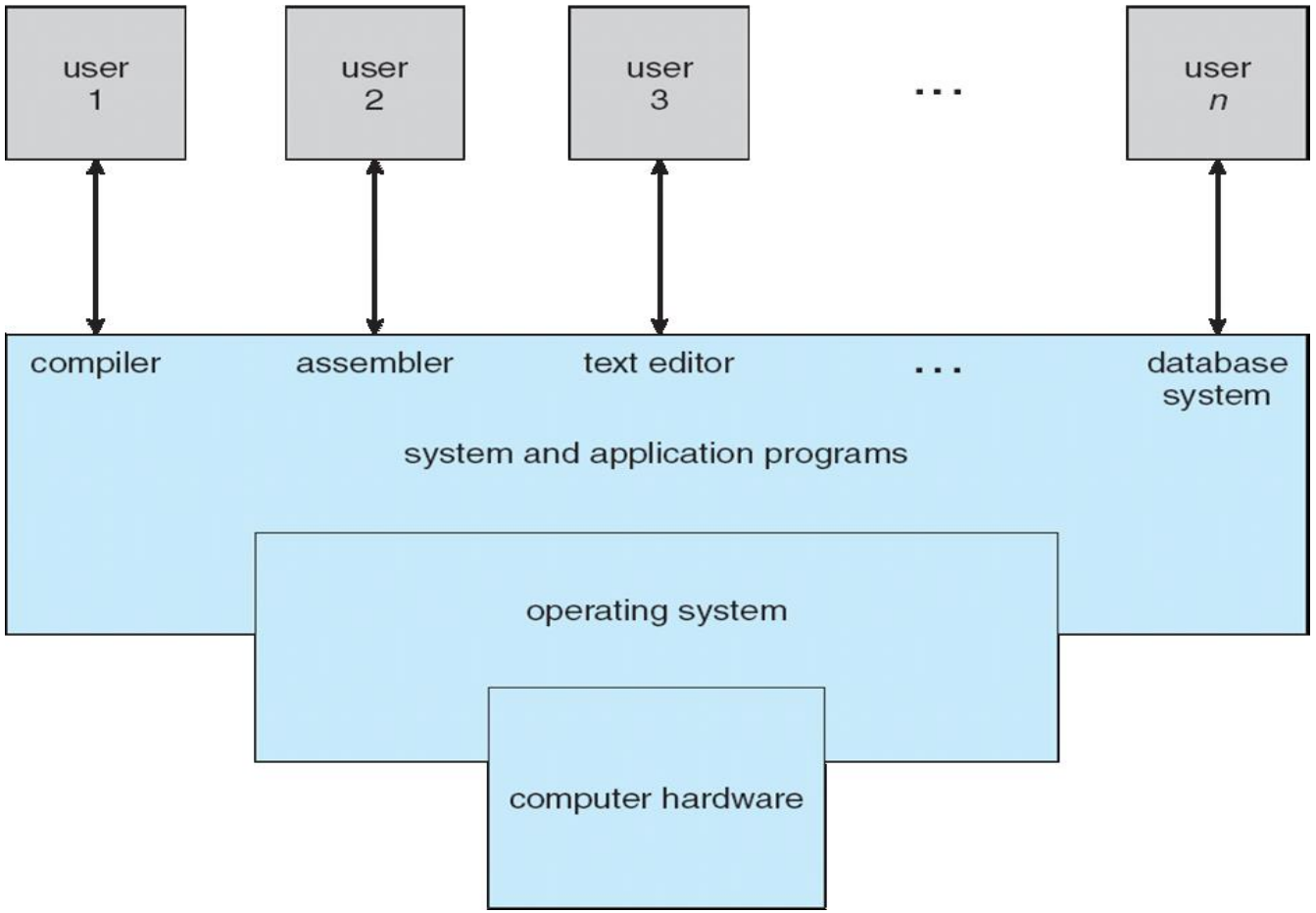
- **Operating system goals:**
  - **Execute user programs and make problem solving easier.**
  - **Make the computer system convenient to use**
  - **Efficiently use available resources**

- An operating system is the one program that is running at all the times on the computer- usually called the kernel.
- Kernel is a program that (allow) let the hardware to recognize and read the program/process.

Computer System Structure

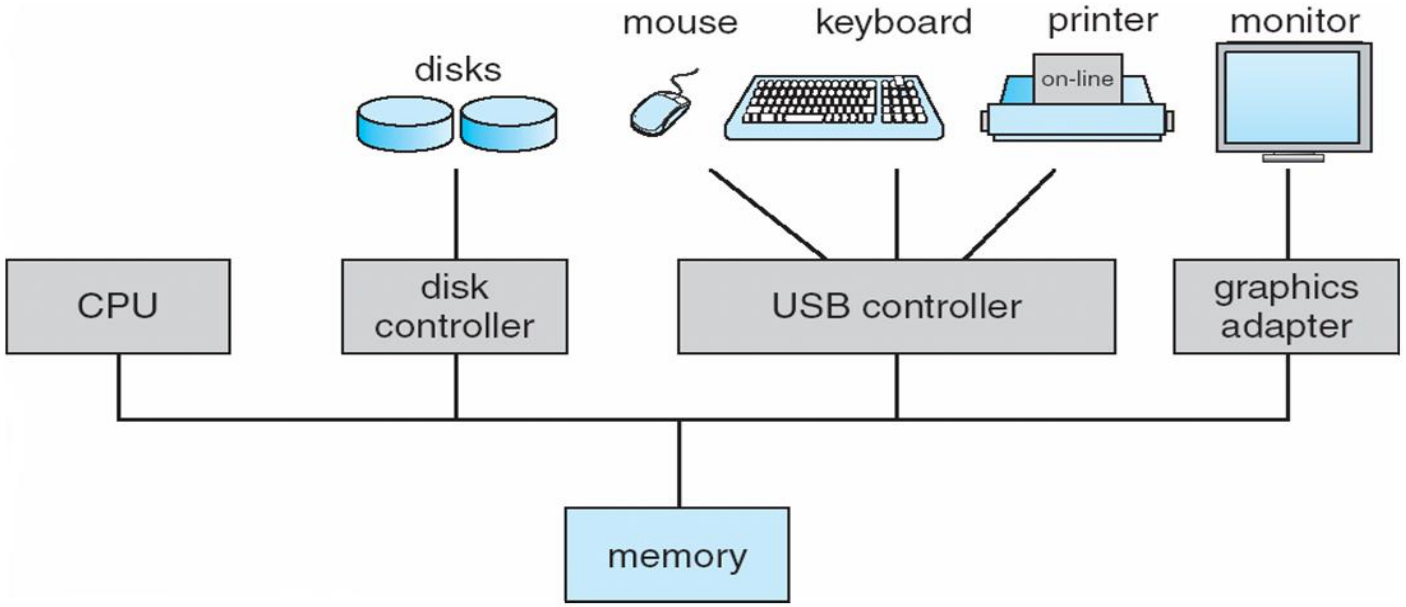
- **Computer system can be divided into four components:**
  - **Hardware** – provides **basic computing resources**
    - CPU, memory, I/O devices
  - **Operating system**
    - **Controls and coordinates use of resources** among various applications and users
  - **System/Application programs** – define the ways in which the system resources are used to solving user problems
    - Word processors, compilers, web browsers, database systems, video games
  - **Users**
    - People, machines, other computers

Four Components of a Computer System



Computer System Organization

- Computer-system operation
  - One or more CPUs, device controllers connect through common bus providing access to shared memory
  - Concurrent execution of CPUs and devices competing for memory cycles



Components of Operating System

1. Process Management
2. File Management
3. Network Management
4. Main Memory Management
5. Secondary Storage Management
6. I/O Device Management
7. Security Management
8. Command Interpreter System

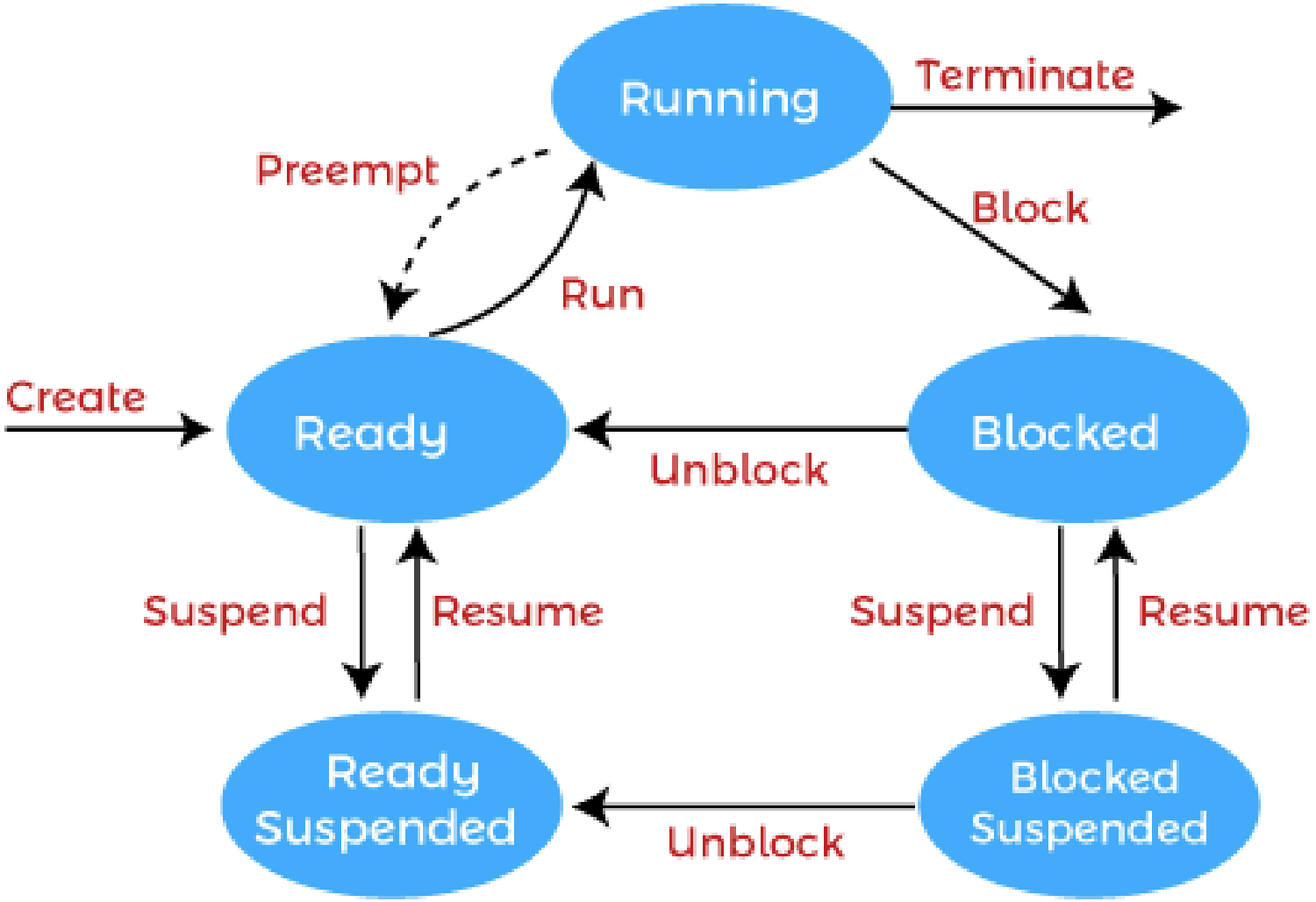

Process Management
File Management
Network Management
Main Memory Management
Secondary Storage Management
I/O Device Management
Security Management
Command Interpreter System
Operating System Components

Process Management

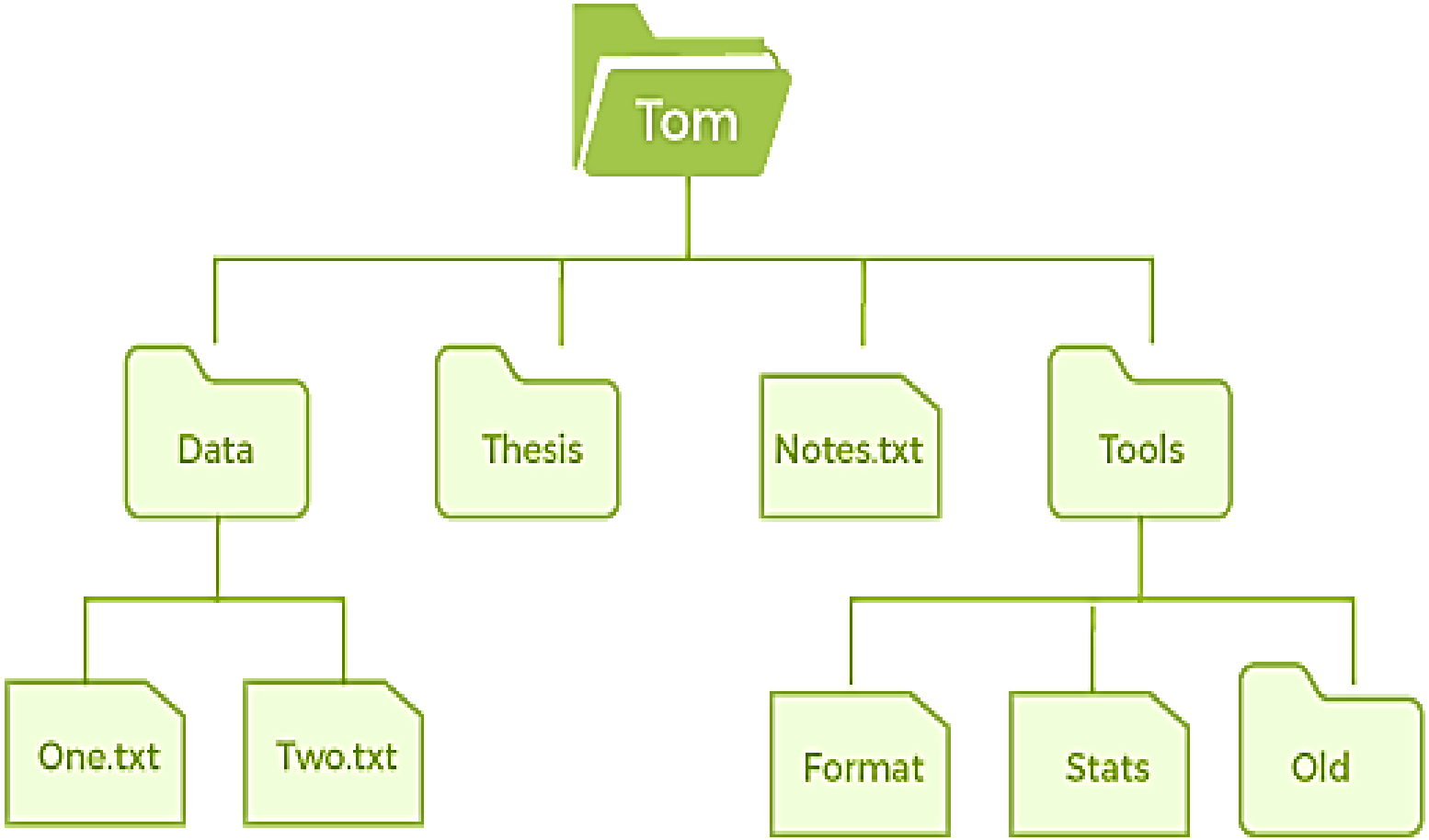
- The process management component is a procedure for managing many processes running simultaneously on the operating system. Every running software application program has one or more processes associated with them.
- For example, when you use a search engine like Chrome, there is a process running for that browser program.
- Process management keeps processes running efficiently. It also uses memory allocated to them and shutting them down when needed.
- The execution of a process must be sequential so, at least one instruction should be executed on behalf of the process.

Functions of process management

- Here are the following functions of process management in the operating system, such as:
- Process creation and deletion.
- Suspension and resumption.
- Synchronization process
- Communication process


Running
Terminate
Preempt
Block
Run
Create
Ready
Blocked
Unblock
Suspend
Resume
Suspend
Resume
Ready Suspended
Blocked Suspended
Unblock

- **File Management**
- A file is a set of related information defined by its creator. It commonly represents programs (both source and object forms) and data. Data files can be alphabetic, numeric, or alphanumeric.
- **Function of file management**
- The operating system has the following important activities in connection with file management:
- File and directory creation and deletion.
- For manipulating files and directories.
- Mapping files onto secondary storage.
- Backup files on stable storage media.


Tom
Data
Thesis
Notes.txt
Tools
One.txt
Two.txt
Format
Stats
Old

- **Network Management**
- Network management is the process of administering and managing computer networks. It includes performance management, provisioning of networks, fault analysis, and maintaining the quality of service.
- A distributed system is a collection of computers or processors that never share their memory and clock.
- In this type of system, all the processors have their local memory, and the processors communicate with each other using different communication cables, such as fibre optics or telephone lines.
- The computers in the network are connected through a communication network, which can configure in many different ways.
- The network can fully or partially connect in network management, which helps users design routing and connection strategies that overcome connection and security issues.

- **Functions of Network management**

- Distributed systems help you to various computing resources in size and function. They may involve minicomputers, microprocessors, and many general-purpose computer systems.
- A distributed system also offers the user access to the various resources the network shares.
- It helps to access shared resources that help computation to speed up or offers data availability and reliability.

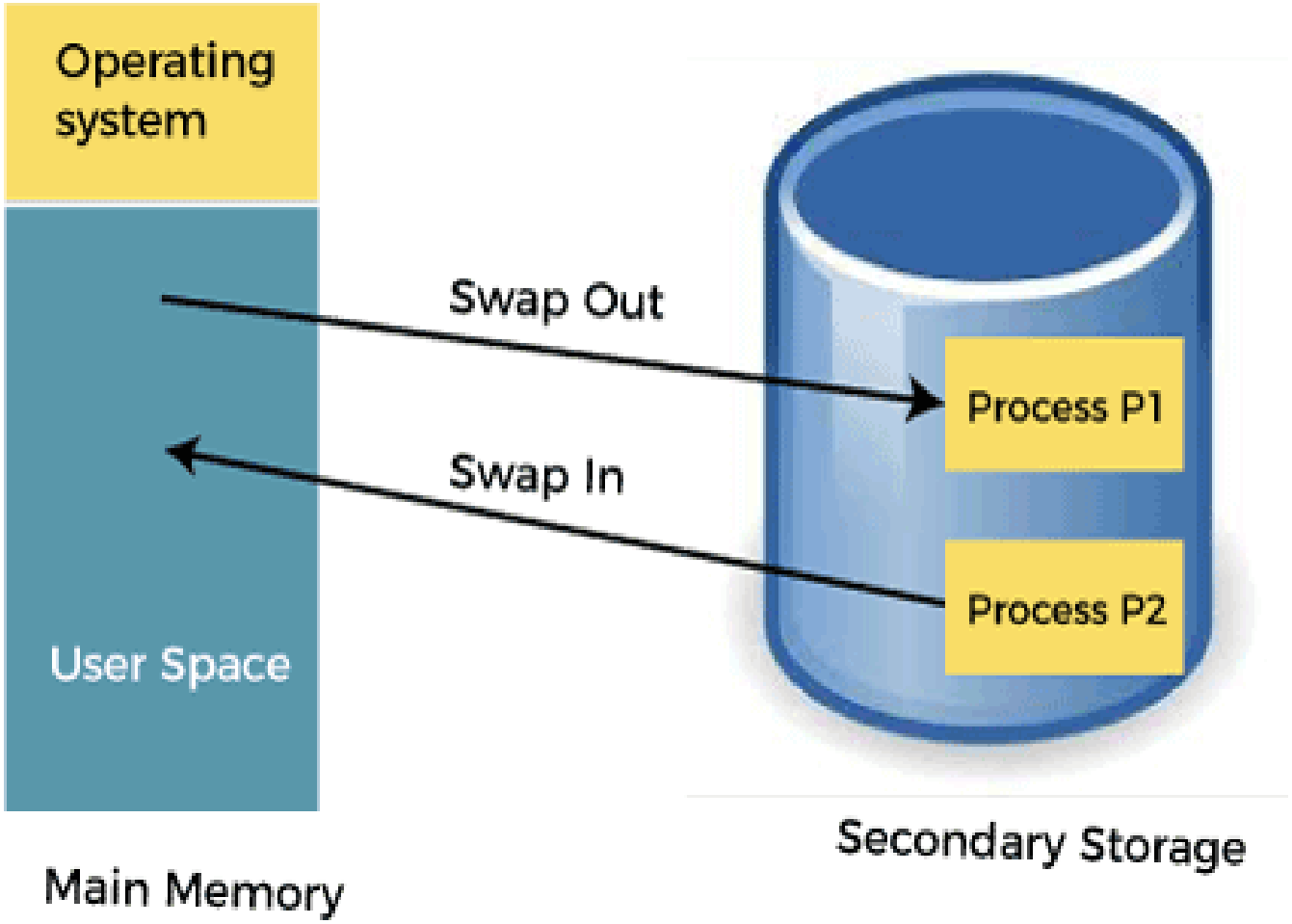
Computer Networks

When we hook up computers together using data communication facilities, we call this a computer network.

- **Main Memory management**
- Main memory is a large array of storage or bytes, which has an address.
- The memory management process is conducted by using a sequence of reads or writes of specific memory addresses.
- It should be mapped to absolute addresses and loaded inside the memory to execute a program. The selection of a memory management method depends on several factors
- However, it is mainly based on the hardware design of the system. Each algorithm requires corresponding hardware support.
- Main memory offers fast storage that can be accessed directly by the CPU. It is costly and hence has a lower storage capacity. However, for a program to be executed, it must be in the main memory.

- **Functions of Memory management**

- An Operating System performs the following functions for Memory Management in the operating system:
- It helps you to keep track of primary memory.
- Determine what part of it are in use by whom, what part is not in use.
- In a multiprogramming system, the OS decides which process will get memory and how much.
- Allocates the memory when a process requests.
- It also de-allocates the memory when a process no longer requires or has been terminated.

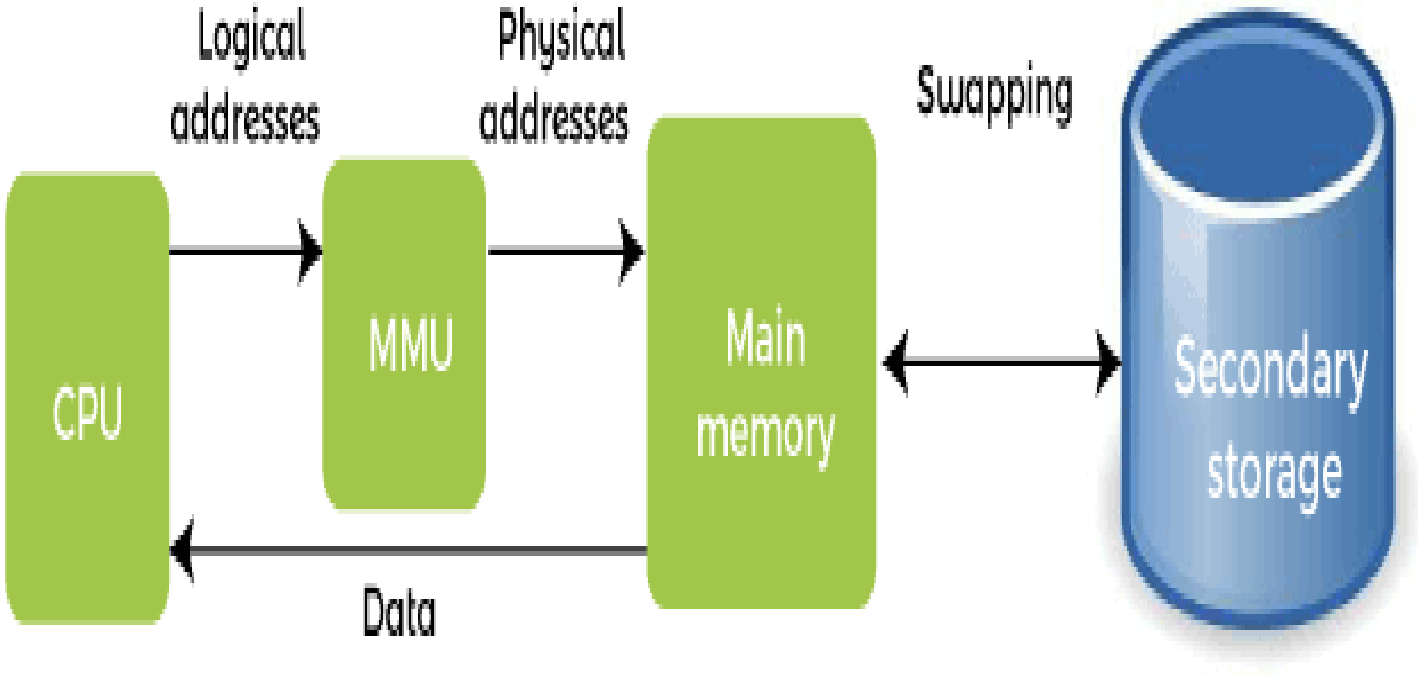

Operating system
User Space
Main Memory
Swap Out
Swap In
Process P1
Process P2
Secondary Storage

- **Secondary-Storage Management**
- The most important task of a computer system is to execute programs. These programs help you to access the data from the main memory during execution.
- This memory of the computer is very small to store all data and programs permanently. The computer system offers secondary storage to back up the main memory.
- Today modern computers use hard drives/SSD as the primary storage of both programs and data.
- However, the secondary storage management also works with storage devices, such as USB flash drives and CD/DVD drives.
- Programs like assemblers and compilers are stored on the disk until it is loaded into memory, and then use the disk is used as a source and destination for processing.

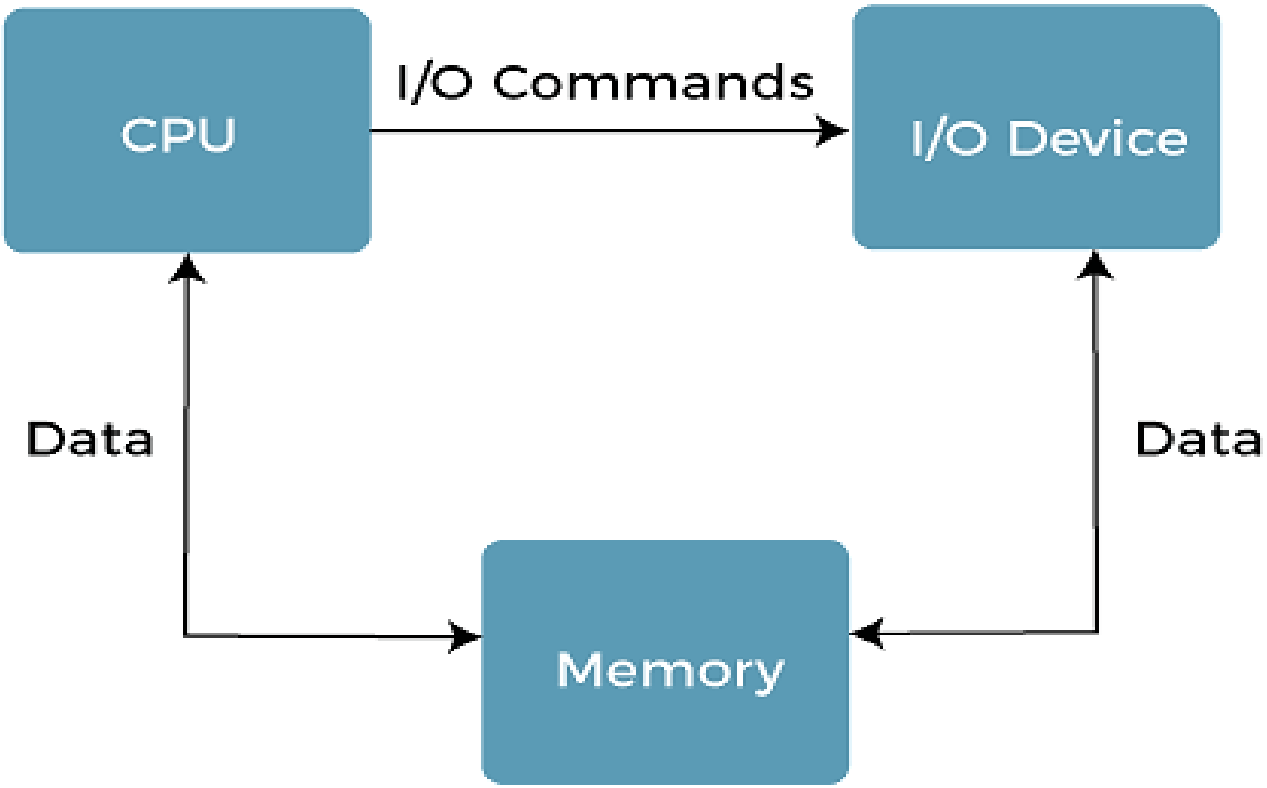
- **Functions of Secondary storage management**

Here are some major functions of secondary storage management in the operating system:

- Storage allocation
- Free space management
- Disk scheduling

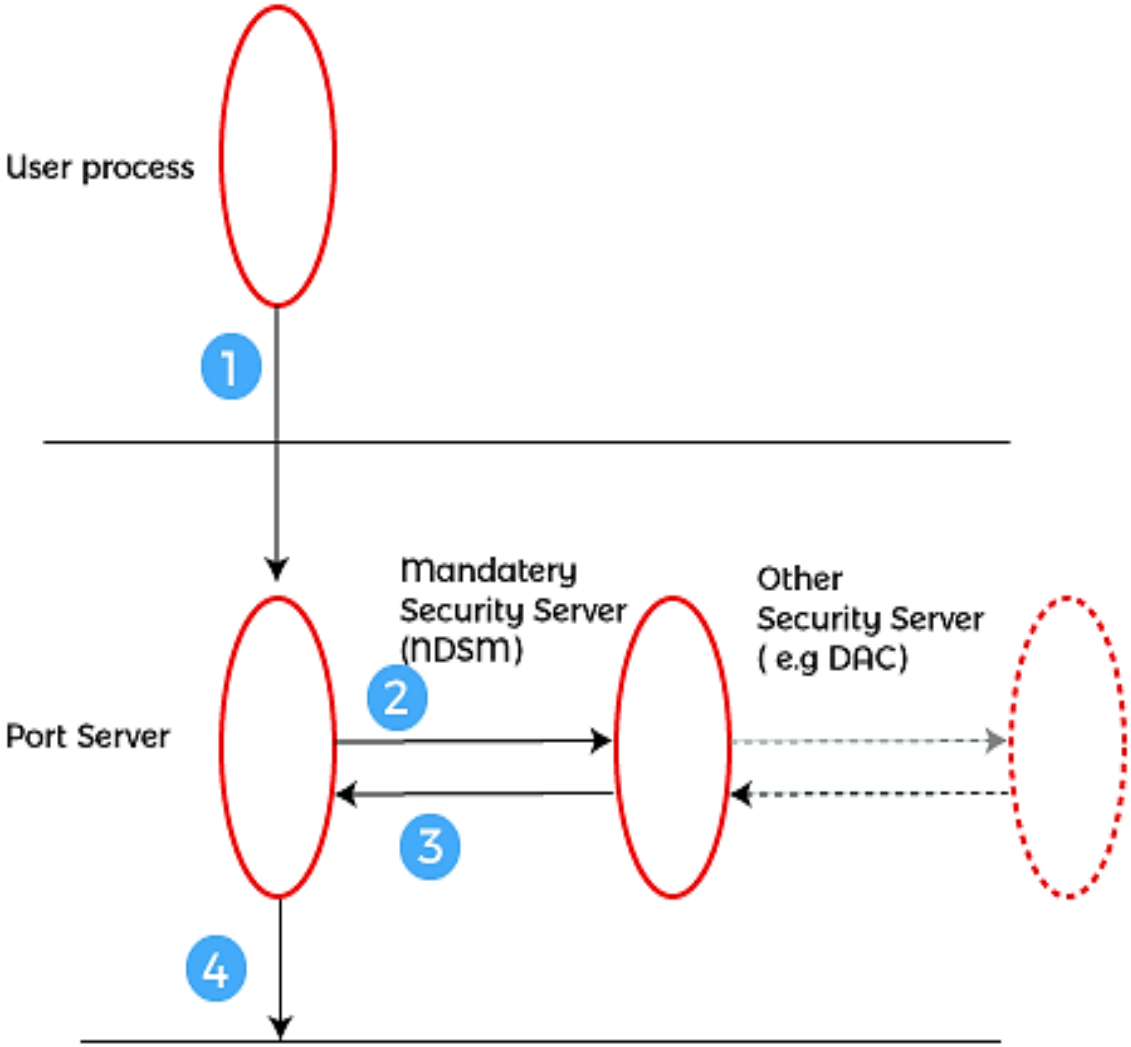

Logical addresses
Physical addresses
Swapping
CPU
MMU
Main memory
Secondary storage
Data

- **I/O Device Management**
- One of the important use of an operating system that helps to hide the variations of specific hardware devices from the user.
- **Functions of I/O management**
- The I/O management system offers the following functions, such as:
- It offers a buffer caching system
- It provides general device driver code
- It provides drivers for particular hardware devices.
- I/O helps you to know the individualities of a specific device.

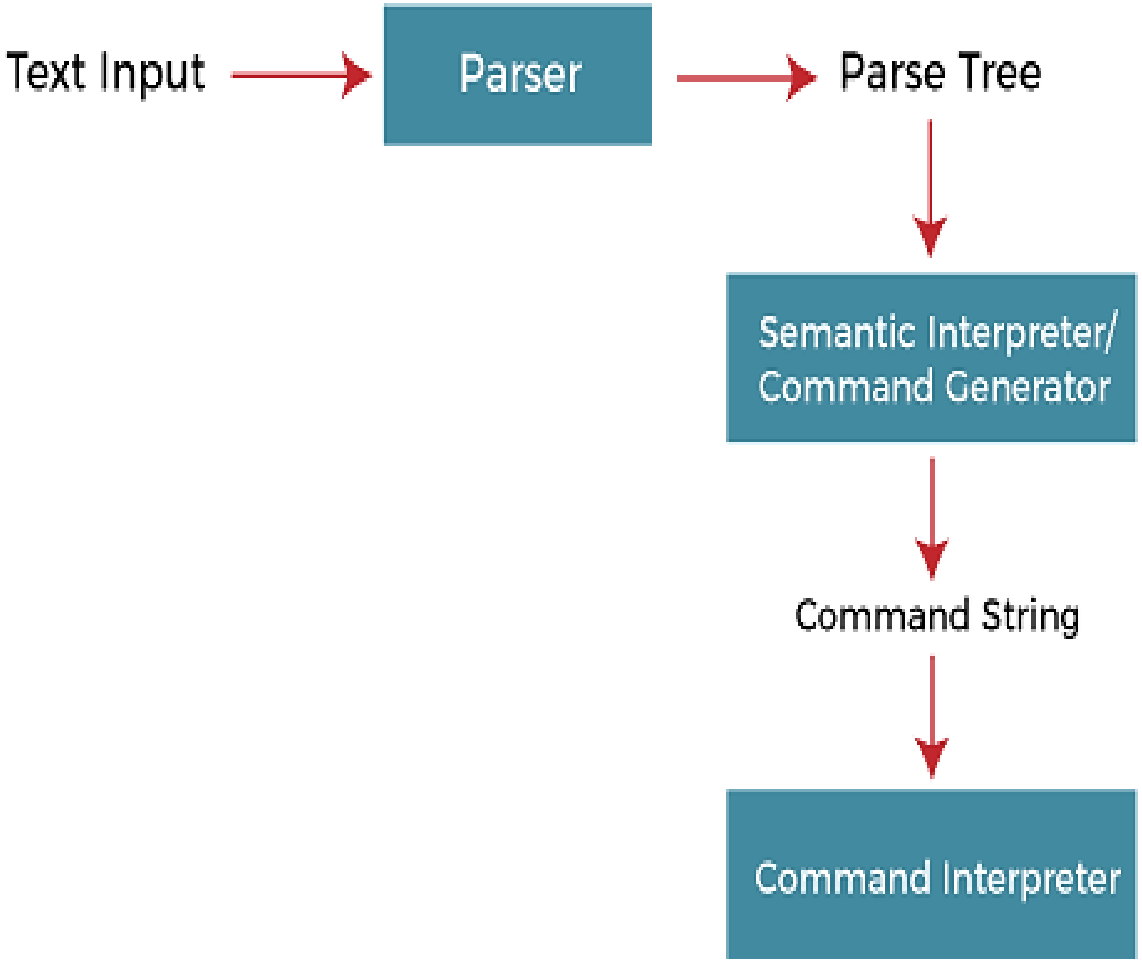

CPU
I/O Commands
I/O Device
Data
Data
Memory

- **Security Management**
- The various processes in an operating system need to be secured from other activities.
- Therefore, various mechanisms can ensure those processes that want to operate files, memory CPU, and other hardware resources should have proper authorization from the operating system.
- Security refers to a mechanism for controlling the access of programs, processes, or users to the resources defined by computer controls to be imposed, together with some means of enforcement.
- For example, memory addressing hardware helps to confirm that a process can be executed within its own address space.
- The time ensures that no process has control of the CPU without renouncing it.

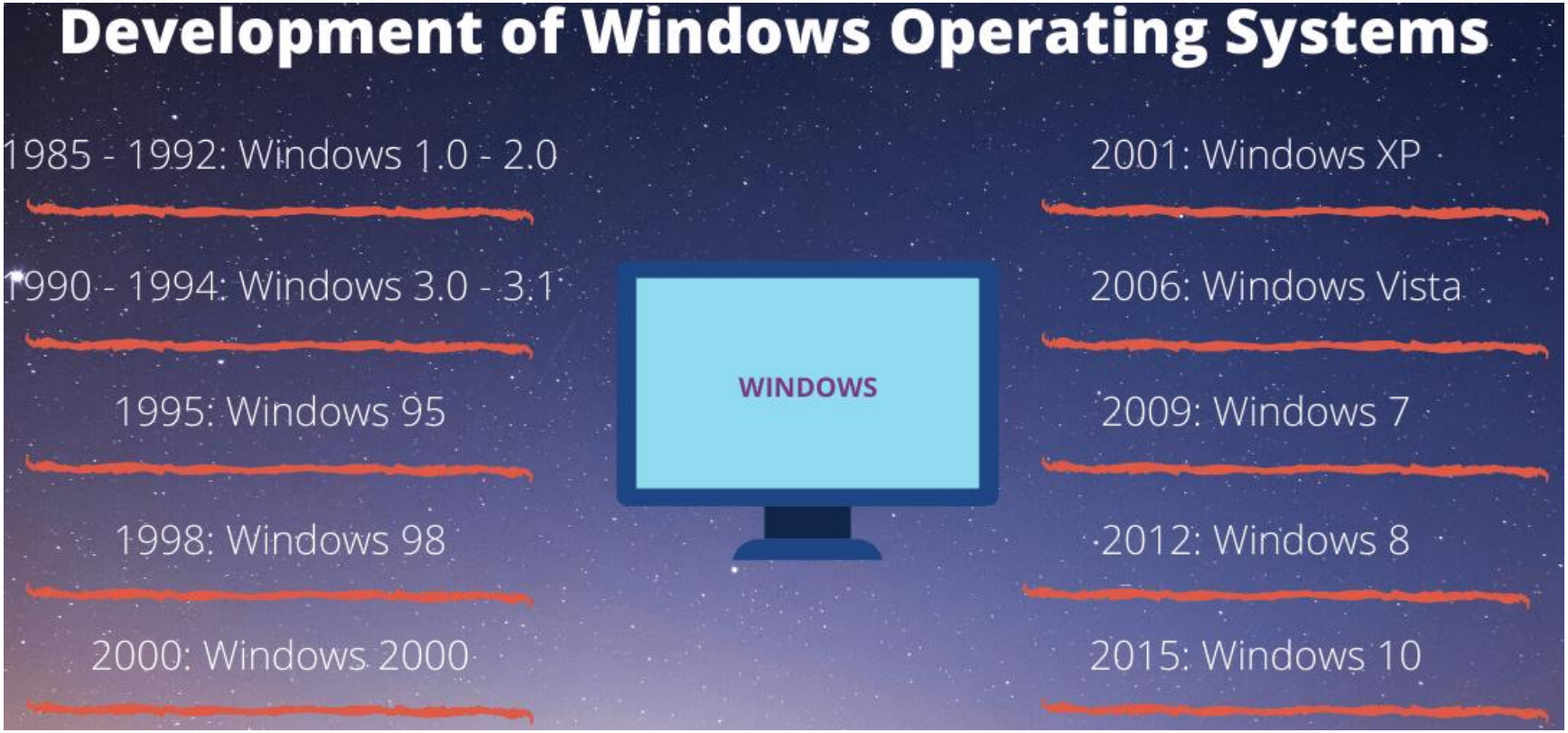
- **Security Management**
- No process is allowed to do its own I/O to protect, which helps you to keep the integrity of the various peripheral devices.
- Security can improve reliability by detecting latent errors at the interfaces between component subsystems.
- Early detection of interface errors can prevent the foulness of a healthy subsystem by a malfunctioning subsystem.
- An unprotected resource cannot misuse by an unauthorized or incompetent user.


User process
1
Mandatery
Security Server
(NDSM)
Other
Security Server
(e.g DAC)
Port Server
2
3
4

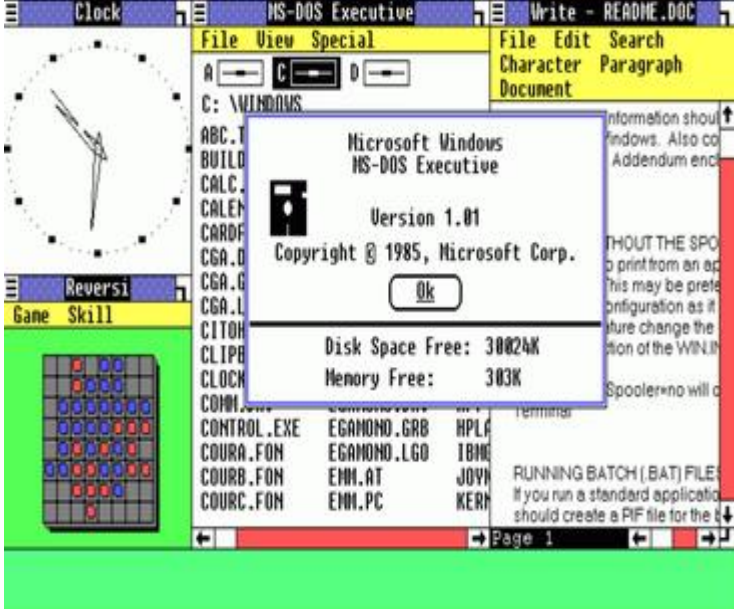
- **Command Interpreter System**
- One of the most important components of an operating system is its command interpreter. The command interpreter is the primary interface between the user and the rest of the system.
- Many commands are given to the operating system by control statements. A program that reads and interprets control statements is automatically executed when a new job is started in a batch system or a user logs in to a time-shared system. This program is variously called:
- The control card interpreter,
- The command-line interpreter,
- The shell (in UNIX), and so on.
- Its function is quite simple, get the next command statement, and execute it. The command statements deal with process management, I/O handling, secondary storage management, main memory management, file system access, protection, and networking.

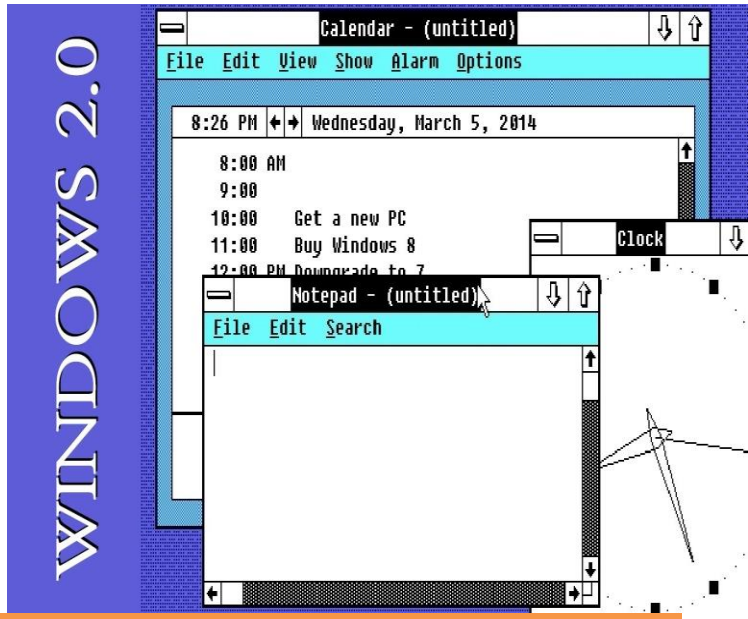

Text Input
Parser
Parse Tree
Semantic Interpreter/
Command Generator
Command String
Command Interpreter

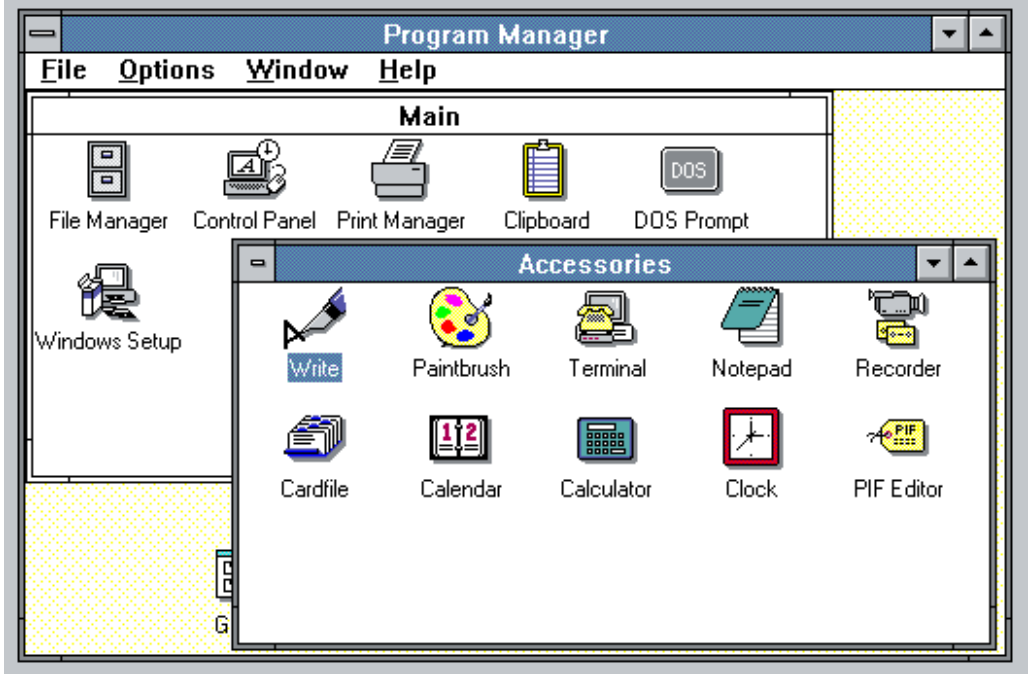
Windows Operating Systems
Versions and features



- **1. Windows 1.0**
- It was released on **November 20, 1985**
- Pure Operating Environment
- Used Graphical User Interface
- Simple Graphics
- Offered limited multi-tasking was expected to have a better future potential
- **2. Windows 2.0**
- It was released on **December 9, 1987**
- 16-bit Graphic User Interface (GUI) based operating environment
- Introduced Control Panel, and the first version of MS Word and Excel
- Unlike Windows 1.0, it had the capacity to allow applications to overlap each other
- It was also the last Windows OS which did not require a hard disk
- Hardware played an important role





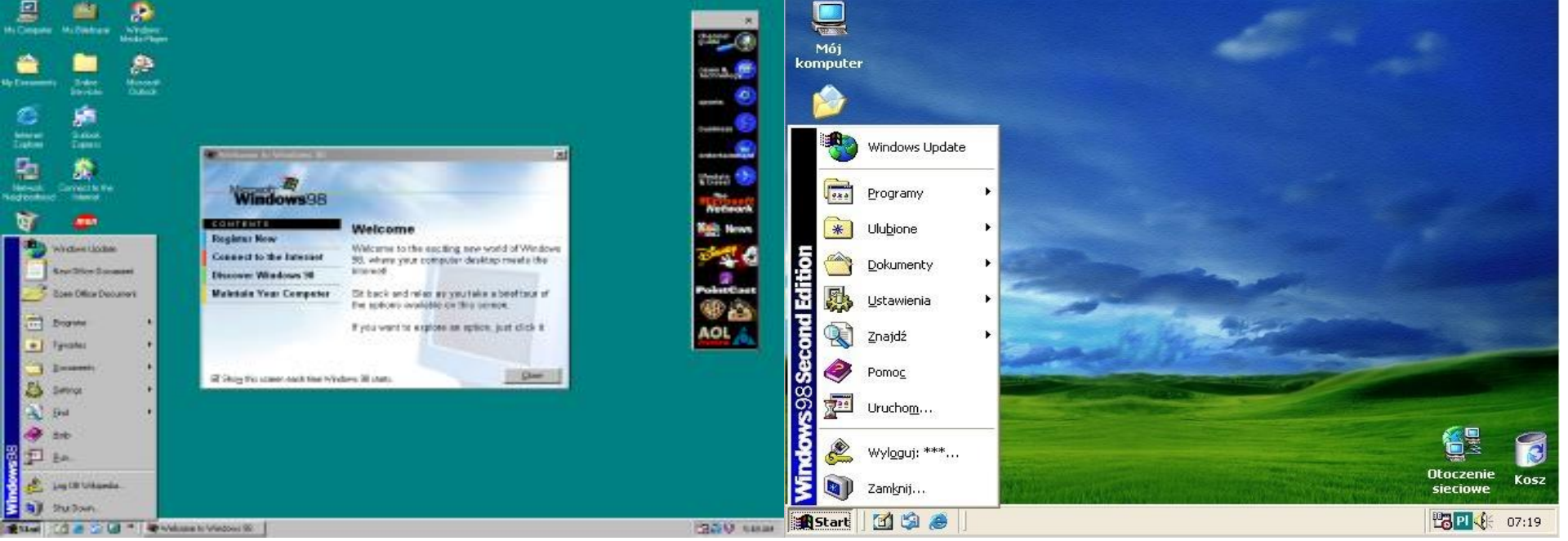


3. Windows 3.0

- It was released in **1990**
- It was better at multitasking
- Used 8086 microprocessors
- It has both, conventional and extendable memory
- First version of Windows to gather critical appreciation
- Better memory/ storage
- **Note*** – None of the above-mentioned Windows was Operating System. They all came under the category of Windows, working based on a graphical operating environment. It was Windows 95, which was the first Operating System released by Microsoft.

4. Window 95

- It was the first complete Operating System
- It was released on **August 15, 1995**
- It merged MS-DOS and Windows products
- It simplified plug-and-play features
- Taskbar and Start menu was introduced with this Windows OS
- Advanced from 16-bit GUI to 32-bit GUI
- Long file names could be saved
- Initially, computers with Windows 95 did not have Internet Explorer installed but by the release date of Windows 95, the first version of Internet Explorer was installed in the software
- On December 31, 2001, Windows declared this version of OS outdated and ended its support for the same



5. Windows 98

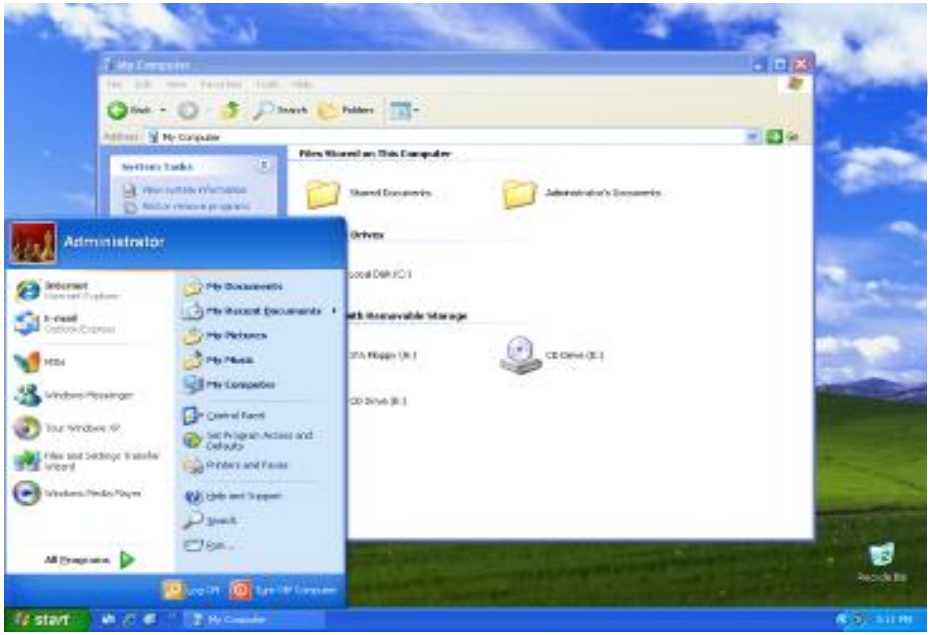
- It was released to manufacturing on **May 15, 1998**
- It was a 16-bit and 32-bit product based on MS-DOS
- It was not an entirely new version but just a tuned-up version of Windows 95
- Internet Explorer 4.01 was released along with this Windows version
- It did not support USB printers or mass-storage devices
- An update to this version “Windows SE” was released in 1999

6. Windows 2000

- It was officially released on **February 17, 2000**. However, its manufacturing had **begun in late 1999**
- A core set of features was followed for manufacturing Windows 2000 but 4 different editions, targeting different sectors of the market were released. These included: Server, Professional, Advanced Server and Datacenter Server
- It was considered one of the most secure OS ever
- A local disk manager was introduced with these Windows
- Multilingual User Interface – it supports many different languages

7. Windows XP

- While the manufacturing started on **August 24, 2001**, the official product was released on October 25, 2001
- Advanced portable PC support
- Automatic wireless connection support
- Fast start-up
- Better Graphical User Interface (GUI)
- Help and support center

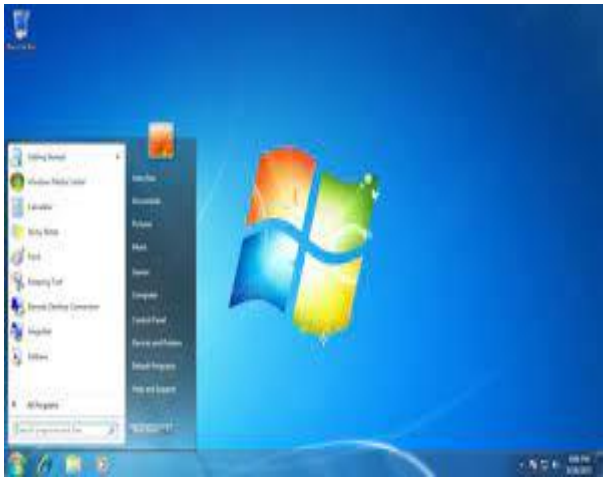


8. Windows Vista

- It was released on **January 30, 2007**
- It had an upgraded version of Graphical User Interface
- It was the first operating system to use DVD-ROM for installation

9. Windows 7

- It was released on **October 22, 2009**
- A large number of new features were introduced
- Redesigned Windows shell with an updated taskbar
- incremental upgrade to the Windows line
- Libraries were added in the file management system
- A few features from the past Windows were removed
- Extended hardware support



10. Windows 8

- It was released for retail on **October 26, 2012**
- Optimizations for touch-based. Installed in new devices like Laptops, Mobile phones, tablets, etc.
- Increased integration with cloud services. Windows Store service for software distribution. The task manager had been redesigned
- New security features were introduced
- Online Applications could be directly downloaded

11. Windows 10

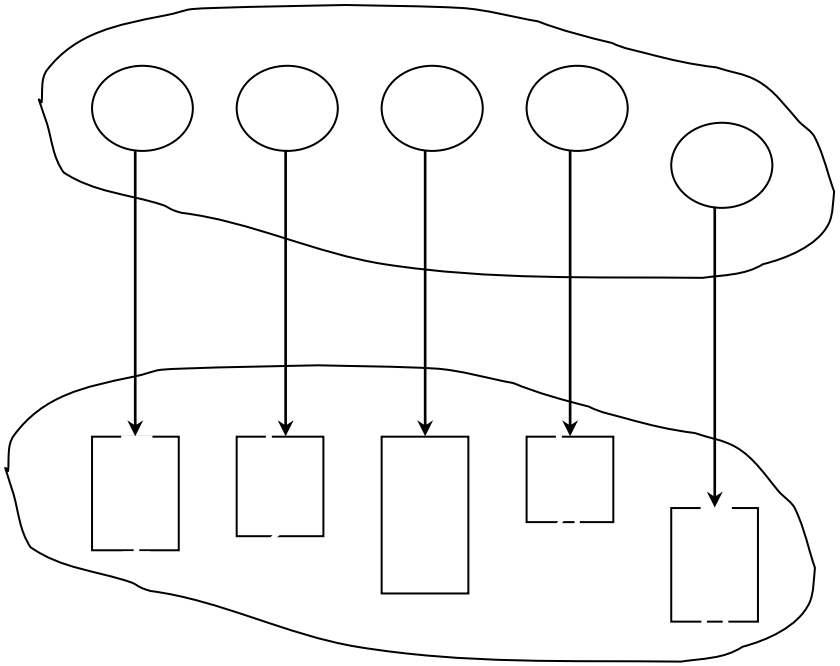
- It was released on **July 29, 2015**
- Addresses shortcomings in the user interface first introduced with Windows 8
- A virtual desktop system
- It had the ability to run Windows Store apps within Windows on the desktop rather than in the full-screen mode
- Included new icons
- To reduce storage shortcomings, Windows 10 automatically compresses the file size

Installation process

1. Set up the display environment
2. Erase the primary boot disk
3. Set up the BIOS
4. Install the operating system
5. Install the operating system, update the drivers, and run operating system updates, as necessary.

Directory Structure

- Symbol table of files that stores all related information about a file it holds with its contents



Both the directory structure and the files reside on disk
Backups of these two structures are kept on tapes

Operations Performed on Directory

Directory: collection of files or directories

- A Symbol Table that translates file names into their directory entry.

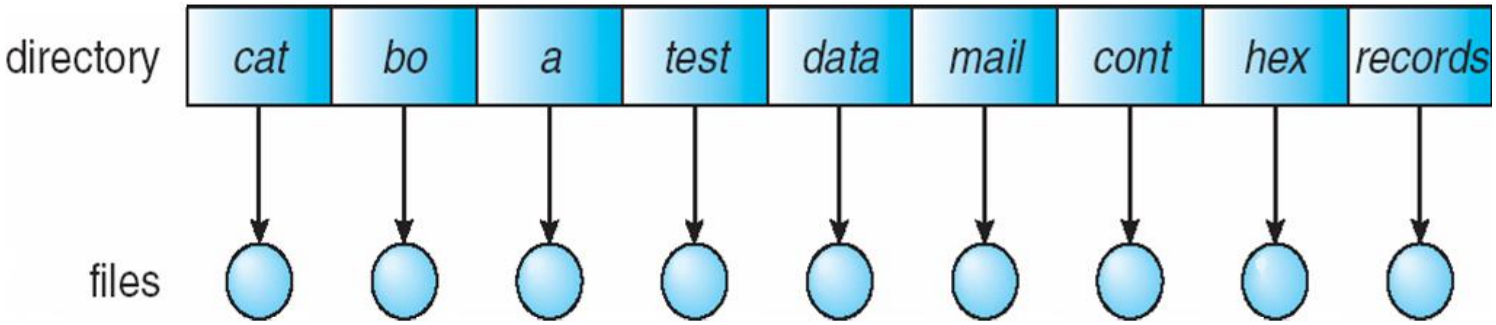
Operations:

- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system : Search all directories/ sub directories and files

Directory Schemes

1. Single Level Directory

One directory many files



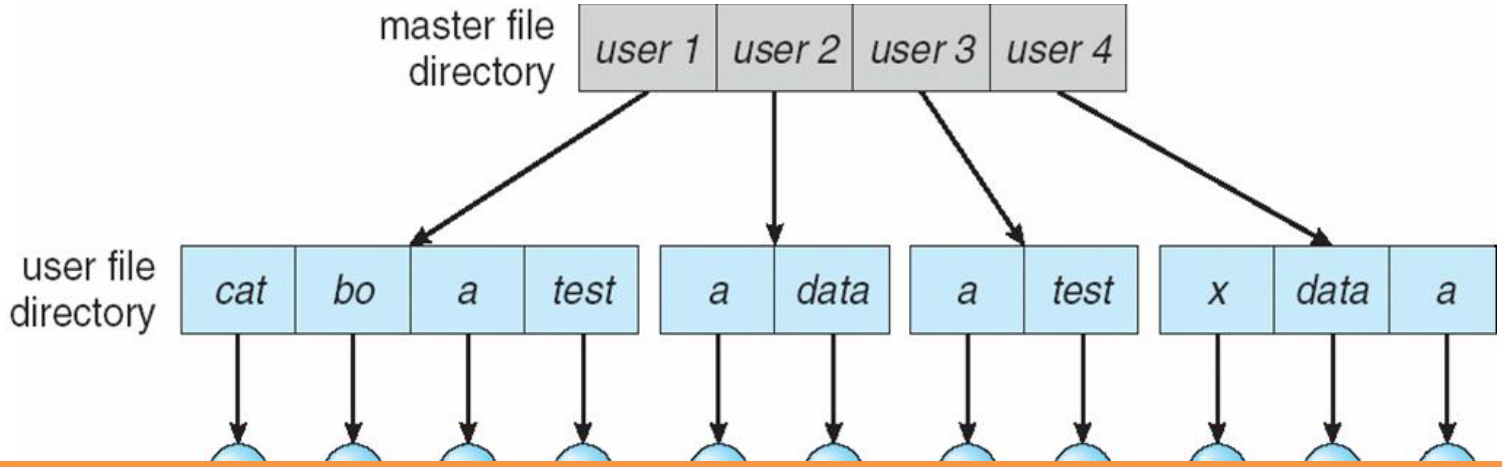
Disadvantage:

1. Difficult to remember the name of files when files increases
2. Single directory for all users
3. File names created by different users should be different.

Two Level

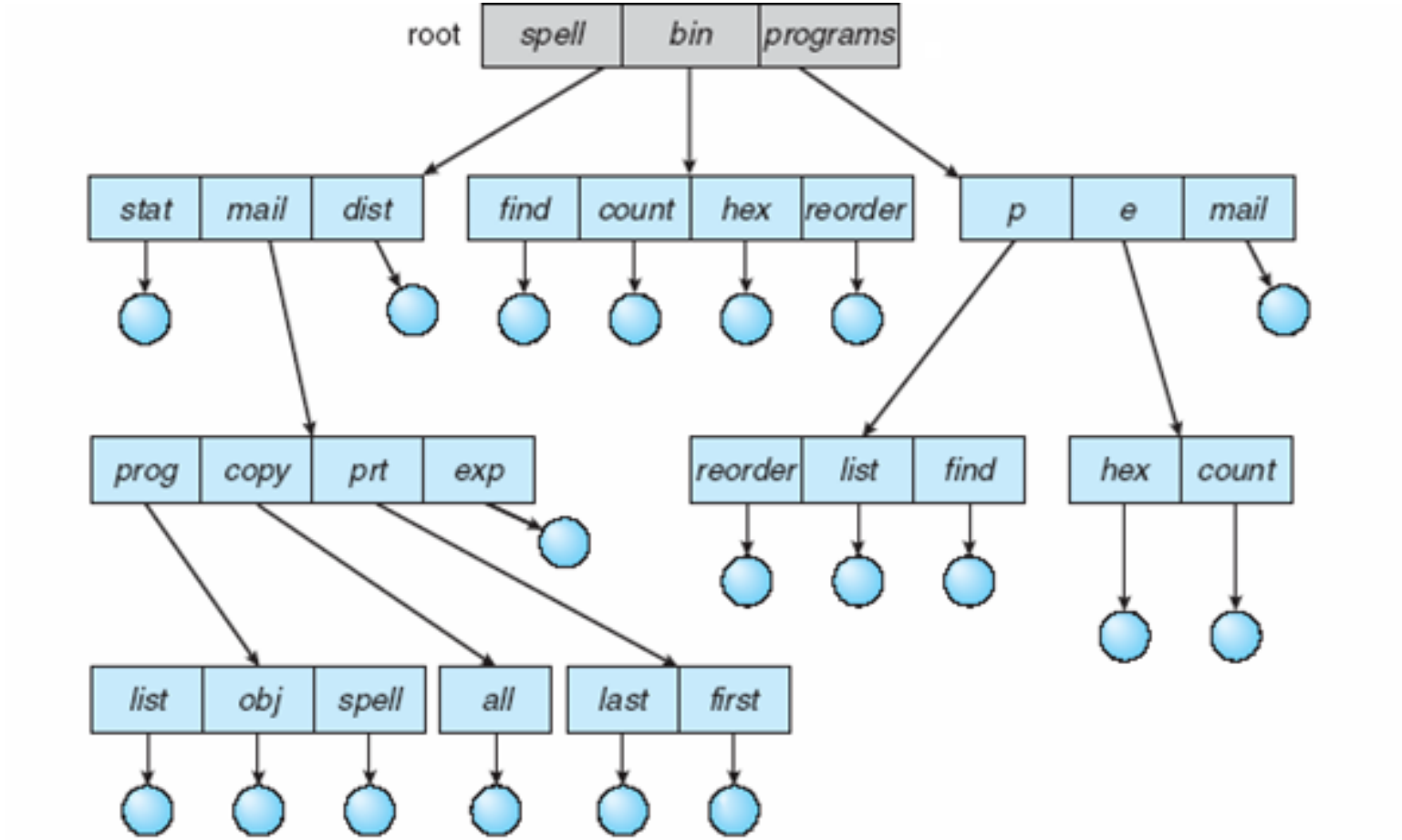
- **2. Two level directory**, **each user has his own user file directory(UFD).**

- UFDs have the similar structure, but each **lists files of a single user**.



Tree Structure

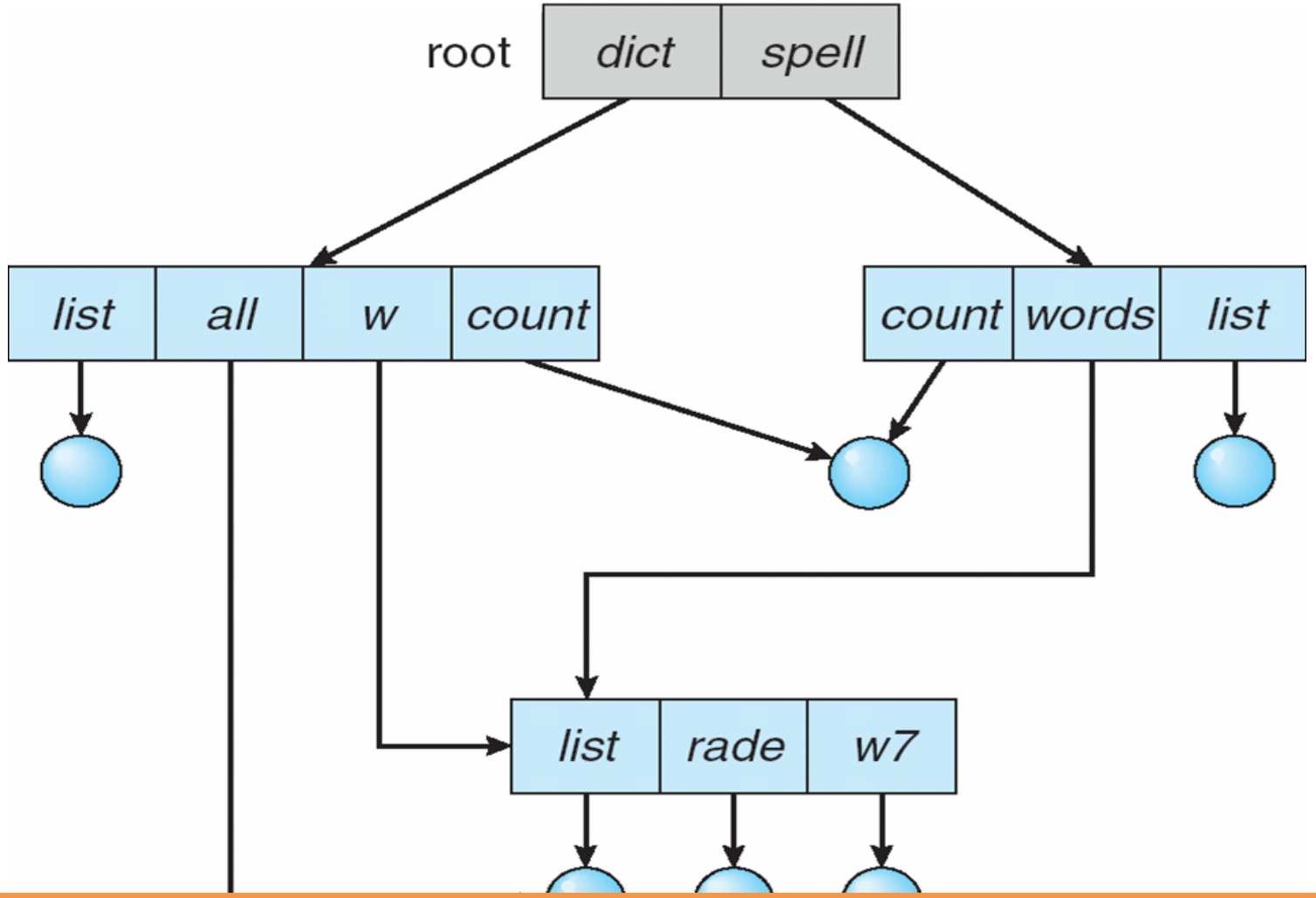
- Users can create their sub directories to manage the files.
- Three has Root directory and files have unique file names



Acyclic-Graph Directories

- Multiple users can Have **shared subdirectories and files**
- **Users have their own working directory** and may have one shared directory
- Shared subdirectory created by one user in one directory is automatically visible to all users sharing that directory.
- Shared directory or file may exist at multiple places simultaneously
- Because of sharing, a file may have multiple absolute paths
- So different names can refer to same file

Acyclic-Graph Directories



General Graph Directories

- Created by adding links to the existing directory
- Allows cycles in the same directory

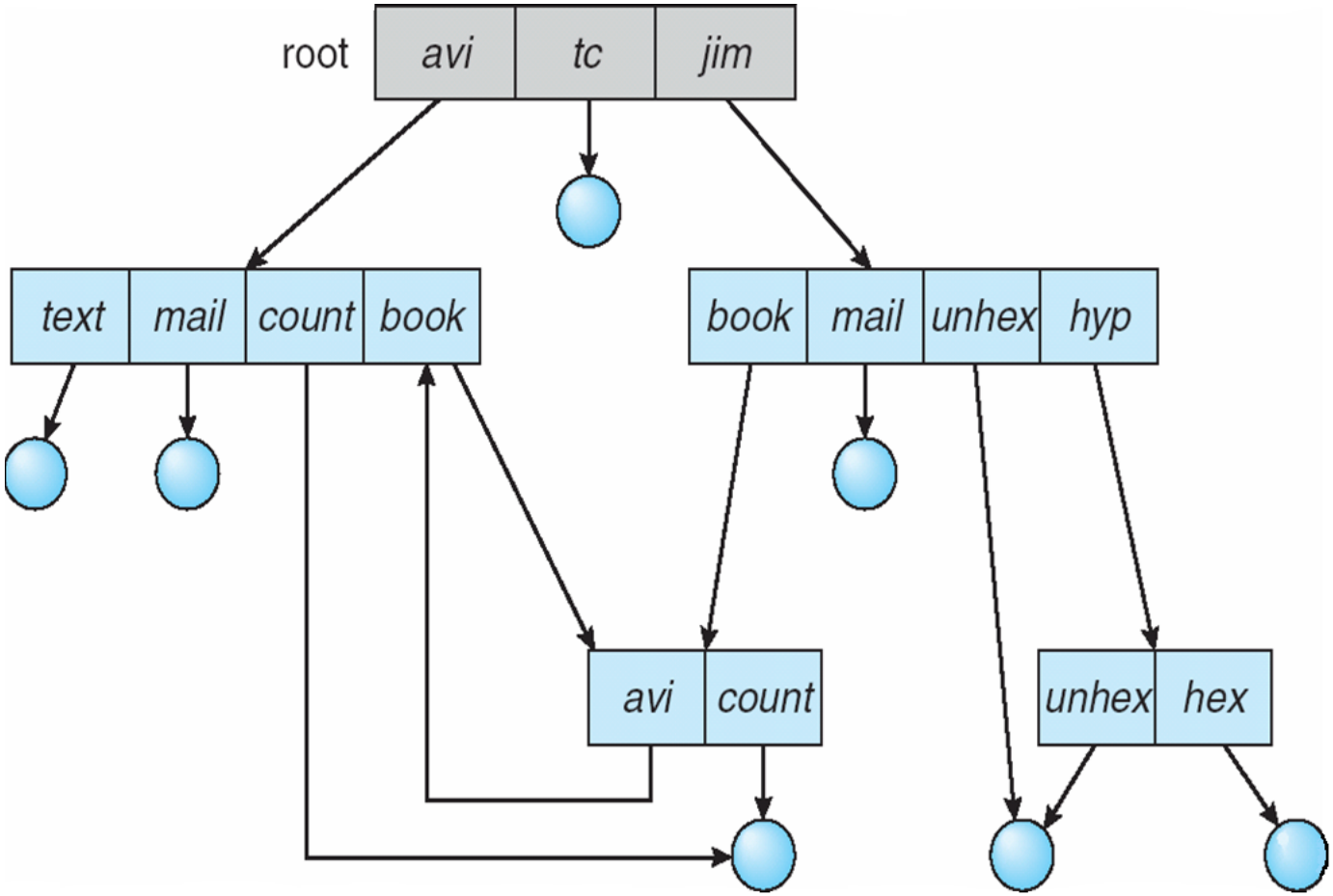
- As all files are dependent / linked deleting a main file may harm other files

- In case of deletion: Garbage Collection is used
- In First Pass: Traversing the entire file and marking everything that can be accessed

- In Second Pass: Collect everything that is not marked as the free space

General Graph Directories

- There can be cycle in the directory arrangement



Directory Implementation

- Directories need to be fast to search, insert, and delete, with a minimum of wasted disk space.

1 Linear List

- A linear list is the simplest and easiest directory structure
- Finding a file requires a linear search.
- Deletions can be done by moving all or one entry to vacant position and deleting the pointer.

2 Hash Table

- A hash table can also be used to speed up searches.
- Implementation is by using Hash value.
- **(Division/Variant Method)**

Bootloader

- A boot loader, also called a boot manager, is a small program that places the operating system (OS) of a computer into memory.
- When a computer is powered-up or restarted, the basic input/output system (BIOS) performs some initial tests, and then transfers control to the Master Boot Record (MBR) where the boot loader resides.
- Most new computers are shipped with boot loaders for some version of Microsoft Windows or the Mac OS.
- If a computer is to be used with Linux, a special boot loader must be installed.

Bootloader

- The two most common boot loaders are known as:
  - LILO (LInux LOader) and
  - LOADLIN (LOAD LINux).

An alternative bootloader, called GRUB (GRand Unified Bootloader), is used with Red Hat Linux.

LILO is the most popular boot loader among computer users that employs Linux as the main, or only, operating system.

Bootloader

- LOADLIN is preferred by some users whose computers have multiple operating systems, and who spend relatively little time in Linux.
- LOADLIN is sometimes used as a backup boot loader for Linux in case LILO fails.
- GRUB is preferred by many users of Red Hat Linux, because it is the default boot loader for that distribution.

File system management

File system management :

File system basics, Types of file systems(FAT, GFT, HFS, NDFS, UDF, Extended file systems), Pipes and redirection, Searching the file system using find and grep with simple regular expressions, Basic process control using signals, pausing and resuming process from a Linux terminal, terminating a process, Adding/removing from search path using PATH variable.

Other Shell commands:

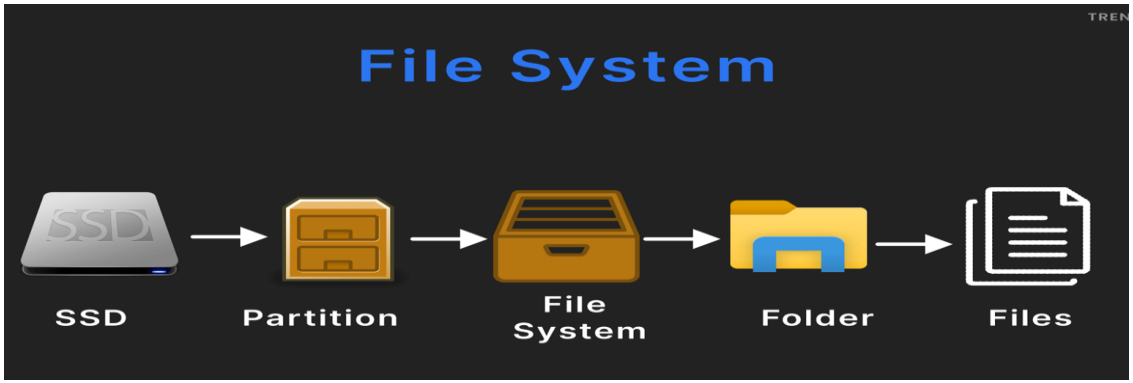
ls, cat, man, cd, touch, cp, mv, rmdir, mkdir, rm, chmod, pwd, ps, kill, etc, Kernel and types of kernels.

Understanding File System

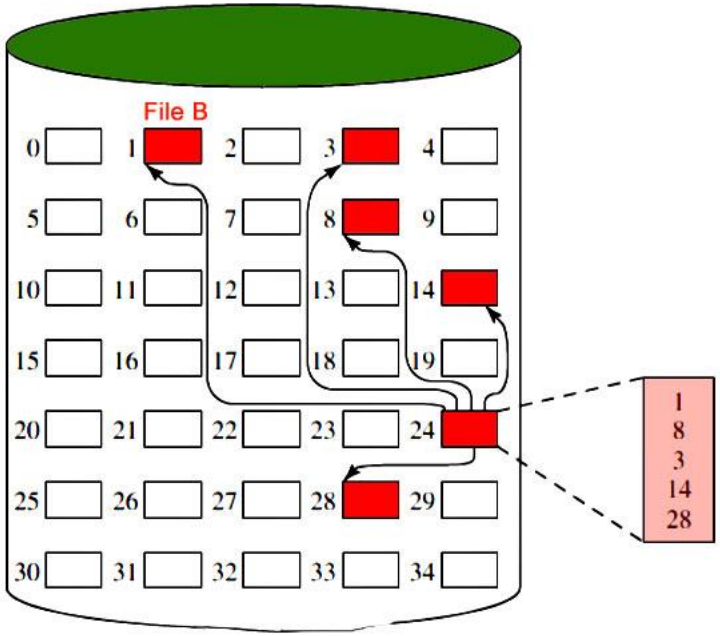
- File system is a structure used to organize data and programs on computer storage devices.

- It keeps track of the physical locations of all data elements on disk and allows users to quickly and reliably retrieve files when needed.

- Every operating system, from MS-DOS to Windows 95, Windows XP and Linux, has its own file system.



Representation of File System



File allocation table

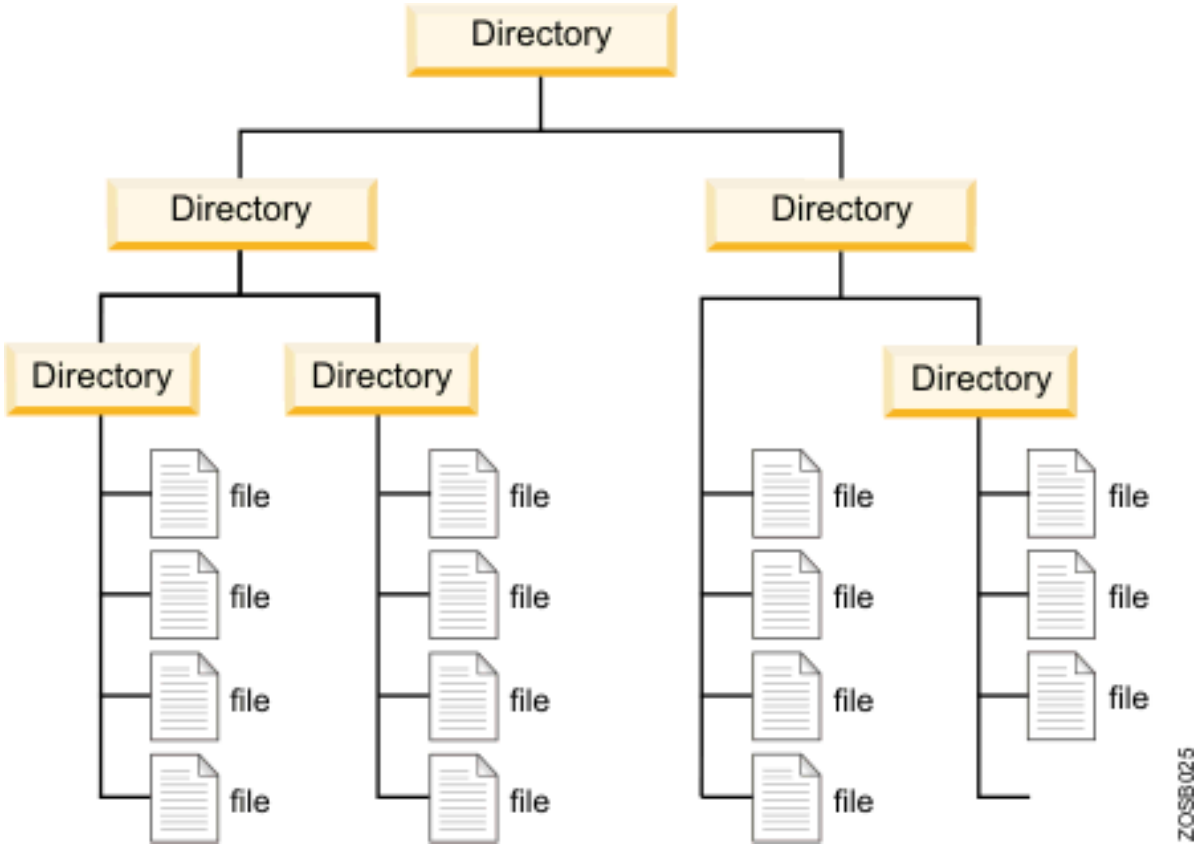
File name	Index block
•••	•••
File B	24
•••	•••

File can be..

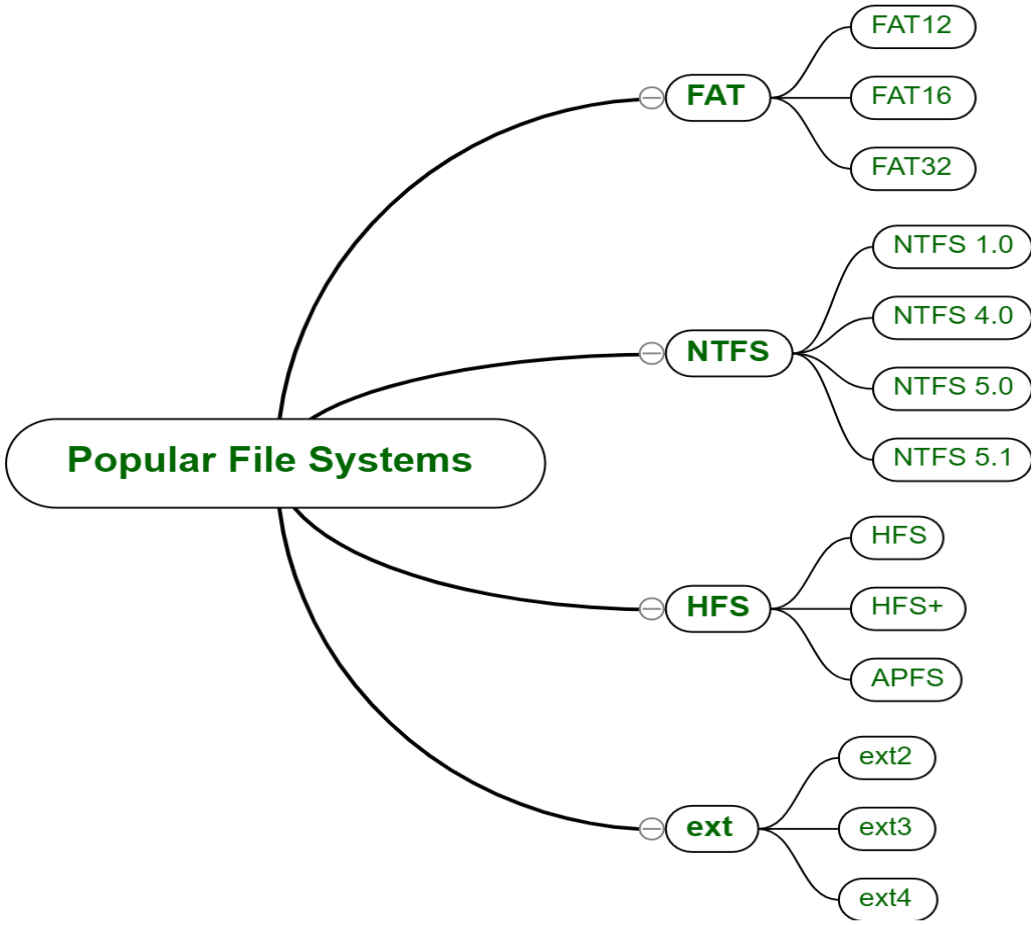
- Regular files
- Directory Files
- Device Files or Special Files

- **Regular Files** stores data (text, binary, and executable)
- **Directory files** contains information used to access other files.
- **Device Files** defines a FIFO (first-in, first-out) pipe file or a physical device

File System Representation



Popular File System



Useful Symbols for Files

Symbol	Meaning
-	regular file (it can be a text file, an executable, a graphic file, an archive, etc.)
d	directory (in linux, directories are files like any other files but the only difference is that they contain other filenames and target to the inodes)
l	a symbolic link (the link file contains the name of the other file or directory; when Linux accesses a symbolic link, it tries to read the target file)
c	character device - a special file (a file that corresponds to a hardware device from which and to which the data is being transferred in 1 B units (1 byte = 8 bits), examples: a parallel port, a RS-232 serial, audio devices)
s	socket - a socket is similar to a connection, but it also allows for both bidirectional and network connections
p	pipes - a pipe activates two programs that run in Linux and communicate with each other; one opens the pipe for reading and the other one opens the pipe for writing, so it is possible to transfer data between programs
b	The block device – it is a file type that corresponds to a hardware device from and to which data is being transferred in blocks larger than 1 B (1 byte = 8 bits); examples: hard drives, USB memories, CD-ROM, and so on.

Types of File Systems

- Following are the various file systems in a device:
  - FAT – File Allocation Table
  - GFS – Global File System
  - HFS – Hierarchical File System
  - DFS – Distributed File System
  - UDF -
  - Extended file system
  - NTFS – New Technology File System

FAT File System

- FAT32
  - Full form is **file allocation table**
  - One of the oldest file systems available on the windows machine.
  - Introduced on ms-dos 7.1 / windows 95 in 1996
  - Developed for floppy disks but later used on hard drive, USB flash drives, and SSD cards.
  - Until windows xp, it was default file system
  - FAT8, FAT12, and FAT16, FAT32 are its variations.

Structure of FAT32 File

FAT32 contd..

Advantages:

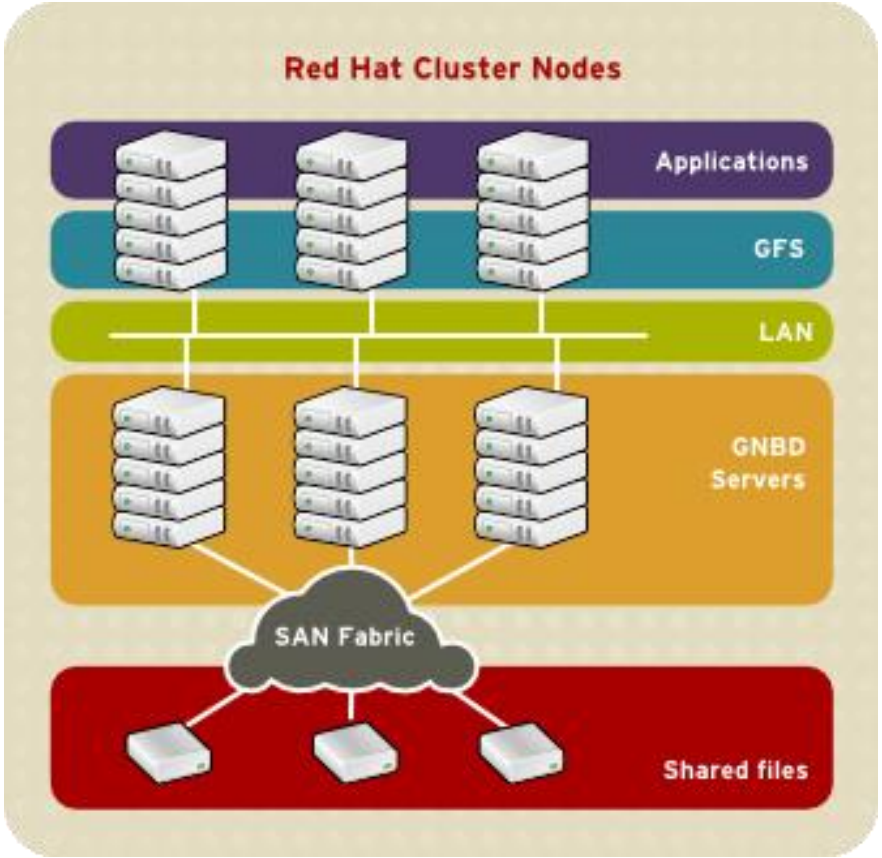
- Can hold up to 268,173,300 files
- The backup FAT table copy gets automatically relocated to the root folder in FAT32 systems, which further can be used for the restoration of files.
- Drive sizes are between 2 and 16 tb with 64kb clusters.
- Is the official format for sd and sdhc cards.

Limitations:

- Each file can have a maximum size of 4GB (GigaBytes).
- No control over file permissions and data security.
- The native disk's maximum disk size for FAT32 is 32 GB. It is possible to expand it up to 2TB.
- FAT32 is no longer used on modern, internal Windows hard drives as most systems have adopted the NTFS standard.

GFS File System

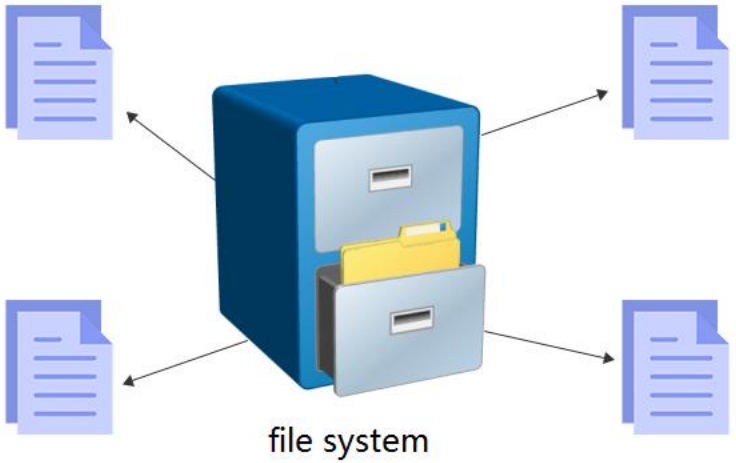
- Full Form is **Global File System**
- Is cluster of files that are shared between a number of computers and end systems from which data or services are accessed, stored and fetched.
- A GFS reads and writes to the remote device



GFS Overview

NTFS (New Technology File System)

- **NTFS:-**
- Current Windows versions beginning with Windows XP — use the NTFS file system to partition their code.
- It is possible to format external drives with either FAT32 or NTFS.



Differences between FAT32, exFAT, and NTFS File Systems.

Sr. No.	Key	FAT32	exFAT	NTFS
1	Introduction	FAT32 was introduced with Windows 95 to replace older FAT16 file system used in DOS and Windows 3.	exFAT was introduced in 2006 with Windows XP and Vista.	NTFS was introduced with Windows NT and widespread usage happened with Windows XP.
2	Features	Easy to use and format. Quick to access.	Suited for Flash drives. Lightweight. Have features but no overhead of NTFS file system.	NTFS supports file permissions, change journal, helps quickly recover from error when computer crashes, shadows copies for backup, provides encryption, disk quota limits, hard linkings etc.
3	Compatability	Works with all versions of Windows, MAC, Linux etc. Any drive having USB port can use FAT32.	Works with all versions of Windows, MAC OS X. Requires additional softwares on Linux.	Compatible with all versions of Windows, Read-Only with MAC and some version of Linux
4	Limitation	Maximum file size 4 GB, Maximum partition file size 8 TB.	No file size or partition size limits.	No file size or partition size limits.
5	Ideal Use	Best for removable drives having max size of 8 TB	Best for flash drives.	Best for Windows System and Internal Drive used by Windows.

HFS File System

- A file with the HFS file extension is an HFS disk image file.
- Known as Hierarchical File System
- Used to store the files on floppy disks, CD-ROM discs, and hard drives of older Apple Macintosh computers.

Btrfs

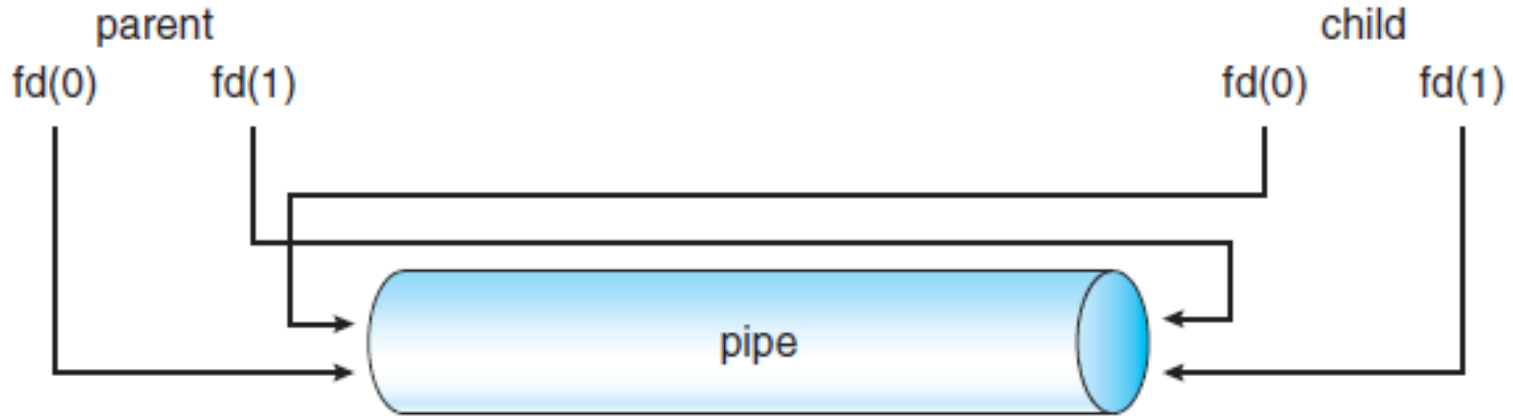
- Btrfs — "better file system" — is a newer, still in development, Linux file system.
- It is a copy-on-write (CoW) filesystem.
- The goal is to provide additional features that allow Linux to scale up to larger storage amounts.

Concept of Pipes and Redirection

A pipe is a connection between two processes, such that the standard output from one process becomes the standard input of the other process.

In UNIX Operating System, Pipes are useful for communication between related processes(inter-process communication).

Although pipe can be accessed like an ordinary file, the system actually manages it as FIFO queue.



Concept of Redirection

Redirection is for files (you redirect streams to/from files).
One common need when we run applications is to direct the output into a file instead of the terminal. A redirect sends a channel of output to a file.

This is typically done with the > operator between the application to run and the file to write the output into. For example, we can send the output of the *ls* command into a file called *files* as follows:
$ ls > files

Searching the File System

- Use command- **find**
  - It search for files in a directory hierarchy under Linux and all other UNIX like operating systems.
  - Examples:
    - find . - name thisfile.txt. ...
    - find /home -name *.jpg. Look for all . ...

Searching the File System contd..

Use command- **grep**

- **Grep** is an acronym that stands for **G**lobal **R**egular **E**xpression **P**rint.

The grep command searches through the file, looking for matches to the pattern specified.

Grep is case-sensitive.

Example:

grep myname biodata

- Here biodata is file and myname is specific pattern for searching in biodata file

Use of grep

Execute the following command to use `grep` to search for every line that contains the word `GNU`:

```
$ grep "GNU" GPL-3
```

Copy Run

The first argument, `GNU`, is the pattern you're searching for, while the second argument, `GPL-3`, is the input file you wish to search.

The resulting output will be every line containing the pattern text:

```
Output
                    GNU GENERAL PUBLIC LICENSE
  The GNU General Public License is a free, copyleft license for
the GNU General Public License is intended to guarantee your freedom to
GNU General Public License for most of our software; it applies also to
  Developers that use the GNU GPL protect your rights with two steps:
  "This License" refers to version 3 of the GNU General Public License.
  13. Use with the GNU Affero General Public License.
under version 3 of the GNU Affero General Public License into a single
...
...
```

On some systems, the pattern you searched for will be highlighted in the output.

Use of grep contd..

Search for each instance of the word `license` (with upper, lower, or mixed cases) in the same file as before with the following command:

```
$ grep -i "license" GPL-3
```

Copy Run

The results contain: `LICENSE`, `license`, and `License`:

```
Output
                    GNU GENERAL PUBLIC LICENSE
 of this license document, but changing it is not allowed.
  The GNU General Public License is a free, copyleft license for
  The licenses for most software and other practical works are designed
the GNU General Public License is intended to guarantee your freedom to
GNU General Public License for most of our software; it applies also to
price.  Our General Public Licenses are designed to make sure that you
(1) assert copyright on the software, and (2) offer you this License
  "This License" refers to version 3 of the GNU General Public License.
  "The Program" refers to any copyrightable work licensed under this
...
...
```

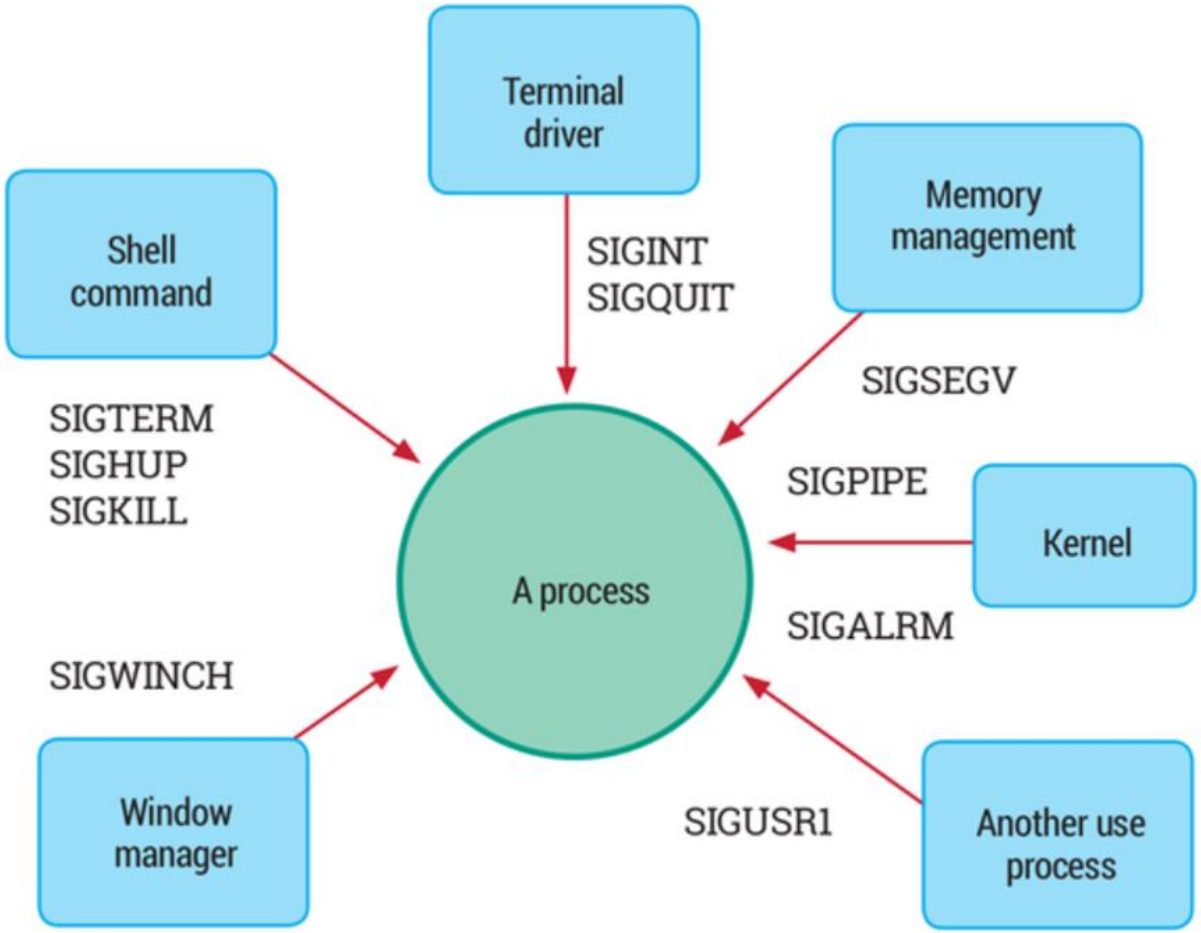
Process Signals

- A signal is basically a one-way notification.
- A signal can be sent by the kernel to a process, by a process to another process, or a process to itself.
- Signals are one of the ways process communicate among themselves and with the kernel.
- The list of the most commonly used signals follow:
- **SIGTERM:** Surprisingly, the default signal sent by kill command.
- Asks the process to terminate voluntarily.
- **SIGKILL:** unlike **SIGTERM,** forces the process to terminate.
- Can't be blocked or handled.
- **SIGSTOP:** suspend the process execution.

Description of Signals

Signal code	Name	Description
1	SIGHUP	Closing the terminal
2	SIGINT	Process stop signal by user from terminal (CTRL + C)
3	SIGQUIT	Signal to stop the process by the user from the terminal (CTRL + \) with a memory dump
nine	SIGKILL	Unconditional termination of the process
15	SIGTERM	Process termination request signal
17	SIGSTOP	Forcibly suspending a process, but not terminating it
18	SIGTSTP	Suspend a process from the terminal (CTRL + Z), but not shutdown
nineteen	SIGCONT	Continuing a previously stopped process

Linux Signals



Kill command

- The **killall** is a Linux only command. It kills processes by names.
- Examples:
  - killall {Process-Name-Here}
  - killall -9 {Process-Name-Here}
  - killall -15 {Process-Name-Here}

- **kill the process using a PID (Process ID)**
  - # kill 3486

  PID can be searched using pgrep command

Path Variable

- It displays or set a search path for executable files at the command line.
- Syntax PATH *pathname* [;*pathname*] [;*pathname*] [;*pathname*]... PATH PATH ; Key pathname : drive letter and/or folder ; : the command 'PATH ;' will clear the path PATH without parameters will display the current path.
- The %PATH% environment variable contains a list of folders.

- The PATH variable is **an environment variable containing an ordered list of paths** that Linux will search for executables when running a command.
  - For example, if we want to print *Hello, world!* in Bash, the command *echo* can be used rather than */bin/echo*, so long as */bin* is in *PATH*: